# KOPIO TN052-A
# FastMC study of interbunch $K_L^0 \to \pi^0\pi^0$ background

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**Abstract**

The background rate from interbunch $K_L^0 \to \pi^0\pi^0$ decays was studied using the FastMC with the $100 \times 5$ mrad$^2$ aspect ratio.

**Added 8 September 2003:** One ns intervals from -6 to +6 ns with respect to the bunch from an original sample of one hundred thousand $K_L^0 \to \pi^0\pi^0$ decays have been added to Figures 1 and 2. Detailed views of the -10 to +10 ns region are provided in Figures 5 and 6. The author (MZ or AK for Mike Zeller or Akira Konaka) of each the seven different sets of cuts is indicated in the Figures.

After conversations with Mike Zeller, we realized it would be useful to identify the source of background suppression as either by kinematics or photon veto. Figures 7 and 8 show the relative loss of $K_L^0 \to \pi^0\pi^0$ rejection for each cut set for kinematics and photon veto combined and for photon veto only.

The apparent increase for the -4ns bin is due to a single high weight event where one photon goes into the upstream beam pipe and is undetected while the remaining photon is relatively low energy (83 MeV).**End 8 September 2003 addition**.

KOPIO will attempt to exploit a bunched primary beam with bunch spacing of 40 ns. Successful reconstruction of the $K_L^0$ center-of-momentum system (CMS) places demands on the interbunch extinction rate. In this note the background rates from $K_L^0 \to \pi^0\pi^0$ decays that occur between bunches are compared to the rate from $K_L^0 \to \pi^0\pi^0$ decays in a bunch.

The FastMC with the $100 \times 5$ mrad$^2$ aspect ratio and Zeller's model of the PR is used. The $K_L^0 \to \pi^0\pi^0$ background rates for seven different sets of cuts, designed to map out the signal/background (S/B) to signal contour are compared at 10 ns intervals with respect to the bunch. Two million $K_L^0 \to \pi^0\pi^0$ decays in the region (950,1350) cm were generated. For each of the 9 times with respect to the bunch center, the same two million decays were smeared, reconstructed and analyzed. The photon and charged particle veto rejection is assumed to be the same for bunch and interbunch $K_L^0$. A reconstructed $\pi^0$ from out-of-bunch $K_L^0$ decay cause the wrong momentum to be assigned to the candidate $K_L^0$.

Figure 1 shows the absolute rate evaluated at each of the 9 different times with respect to the bunch center. Figure 2 shows the rates for each cut set relative to the bunch center. Only statistical uncertainties are shown.

Figure 3 show the induced bias in the $\pi^0$ momentum in the $\mathrm{K^0_L}$ CMS, $P^*(\pi^0)$, for the 9 different times. At -10 ns with respect to the bunch, the induced bias moves the $\mathrm{K^0_L} \rightarrow \pi^0\pi^0$ 'even' background into the signal region as clearly demonstrated by the $P^*(\pi^0)$ *vs* $|E^*_{\gamma 1} - E^*_{\gamma 2}|$ distributions in Figure 4. $E^*_{\gamma i}$ is the CMS energy of the $i^{\mathrm{th}}$ candidate photon daughter of the $\pi^0$.

Although the different cut sets produce different rates, the analysis shows that interbunch events that occur within $\pm 20$ ns of the bunch are the most pernicious and produce rates comparable to or exceeding the bunch rate. Interbunch extinction of $r = 10^{-2}$/ns or better will be needed to suppress interbunch $\mathrm{K^0_L} \rightarrow \pi^0\pi^0$ rates to levels below the bunch rate where $r$ is the number of interbunch $\mathrm{K^0_L}$ per nanosecond divided by the number of $\mathrm{K^0_L}$ in the bunch. Other backgrounds, that are also heavily suppressed by $P^*(\pi^0)$ cuts, such as $\mathrm{K^0_L} \rightarrow \pi^0\pi\pi$, probably necessitate greater total interbunch extinction rates.

Thanks to Laur Littenberg for suggesting this study and to Laur and Michael Sivertz for providing comments and suggestions.

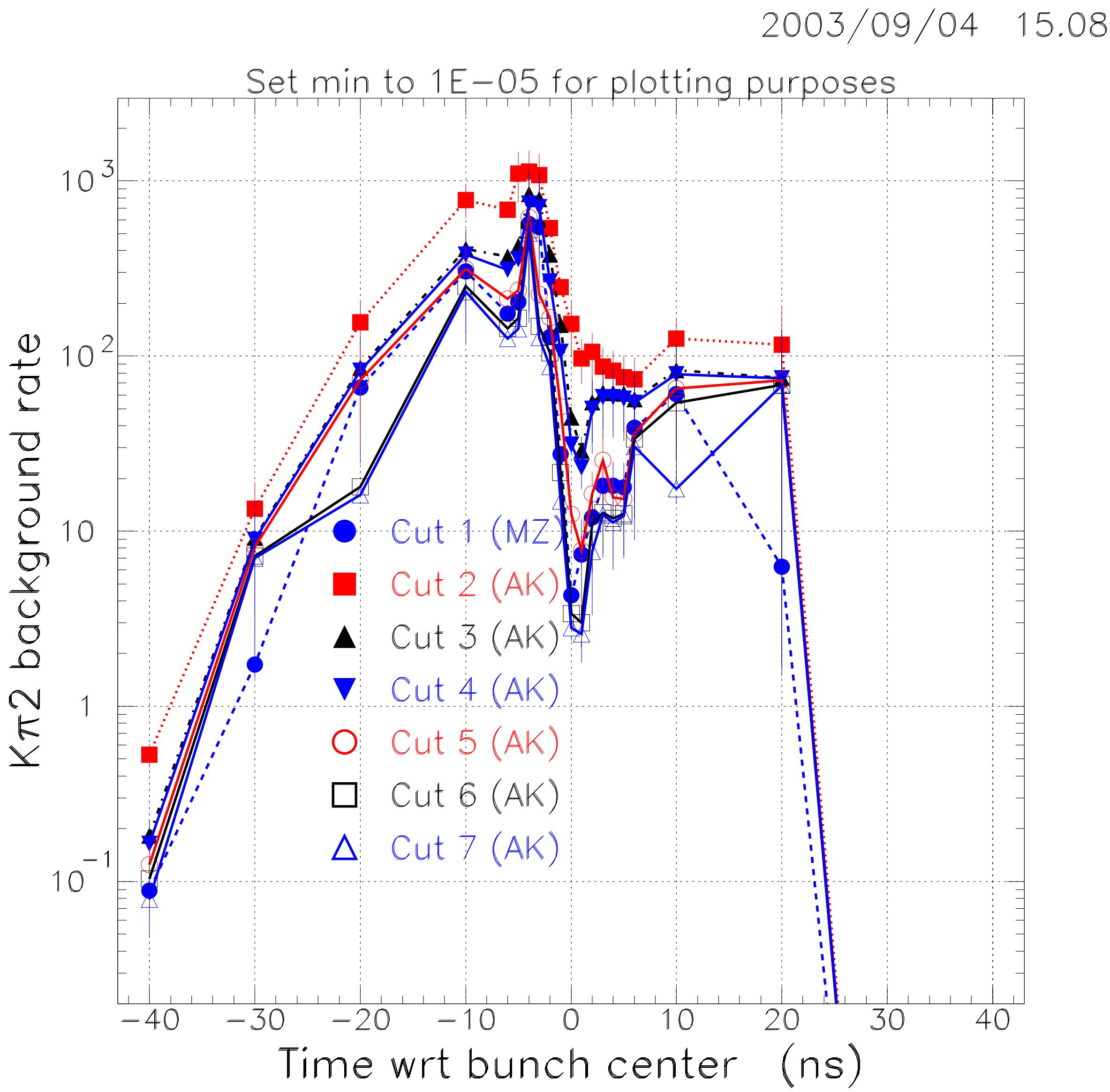


Figure 1: Absolute $K_L^0 \to \pi^0\pi^0$ background rates with respect to the bunch center.

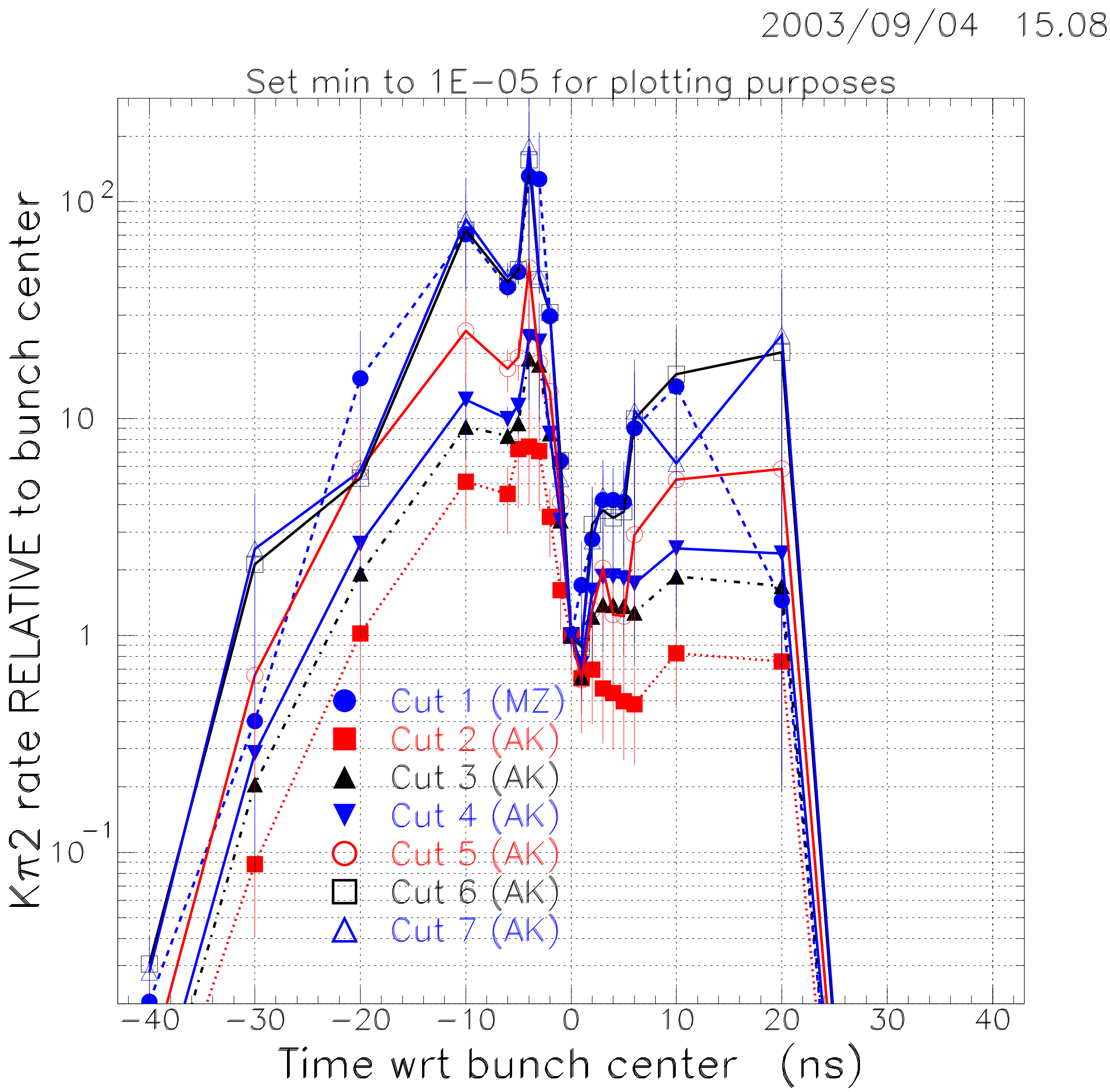


Figure 2: Relative $K^0_L \to \pi^0\pi^0$ background rates with respect to the bunch center.

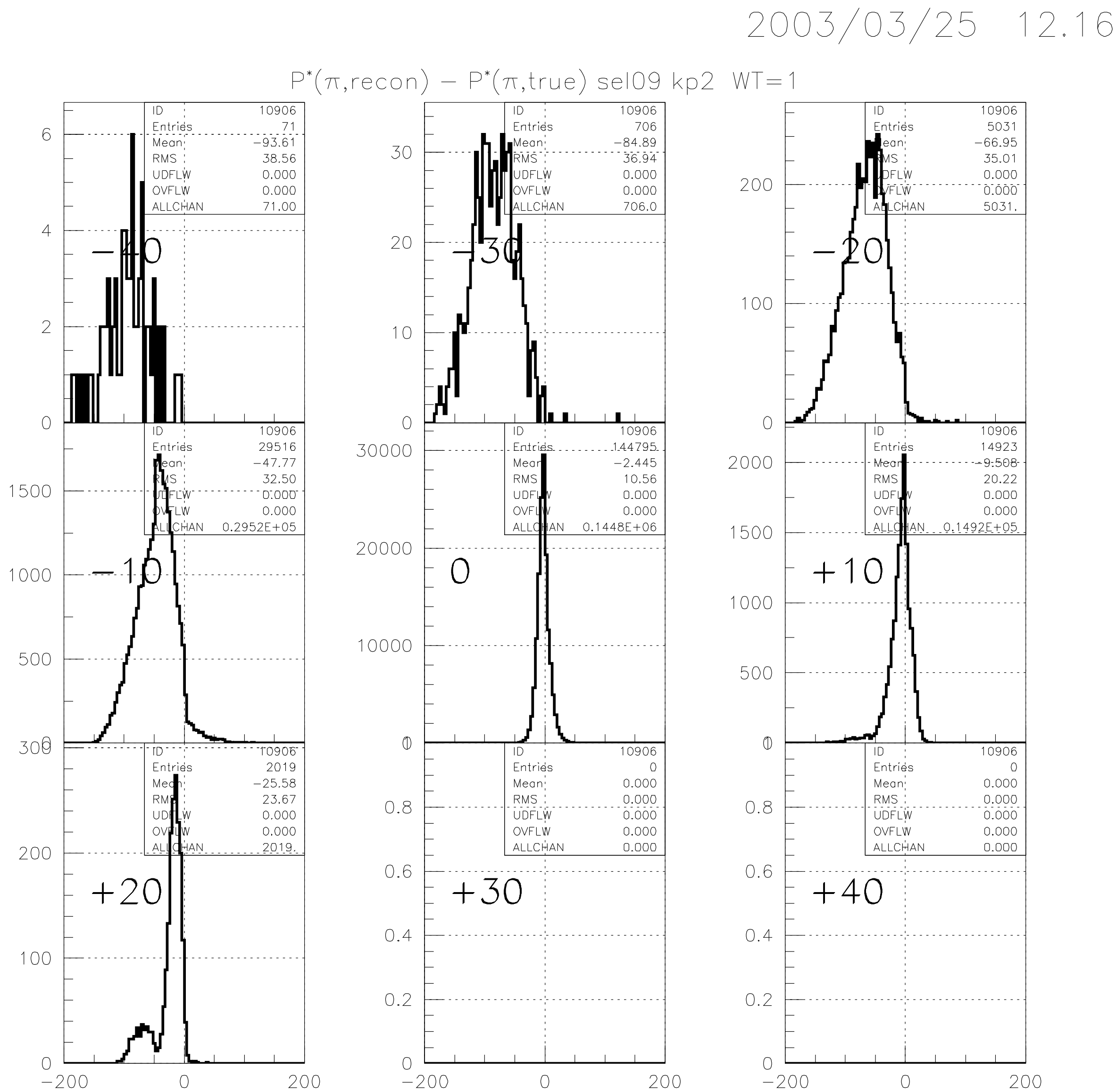


Figure 3: The measured bias in $P^*(\pi^0)$, for the 9 different times with respect to the bunch. The large bold numbers superimposed on each plot give the time relative to the bunch in ns.

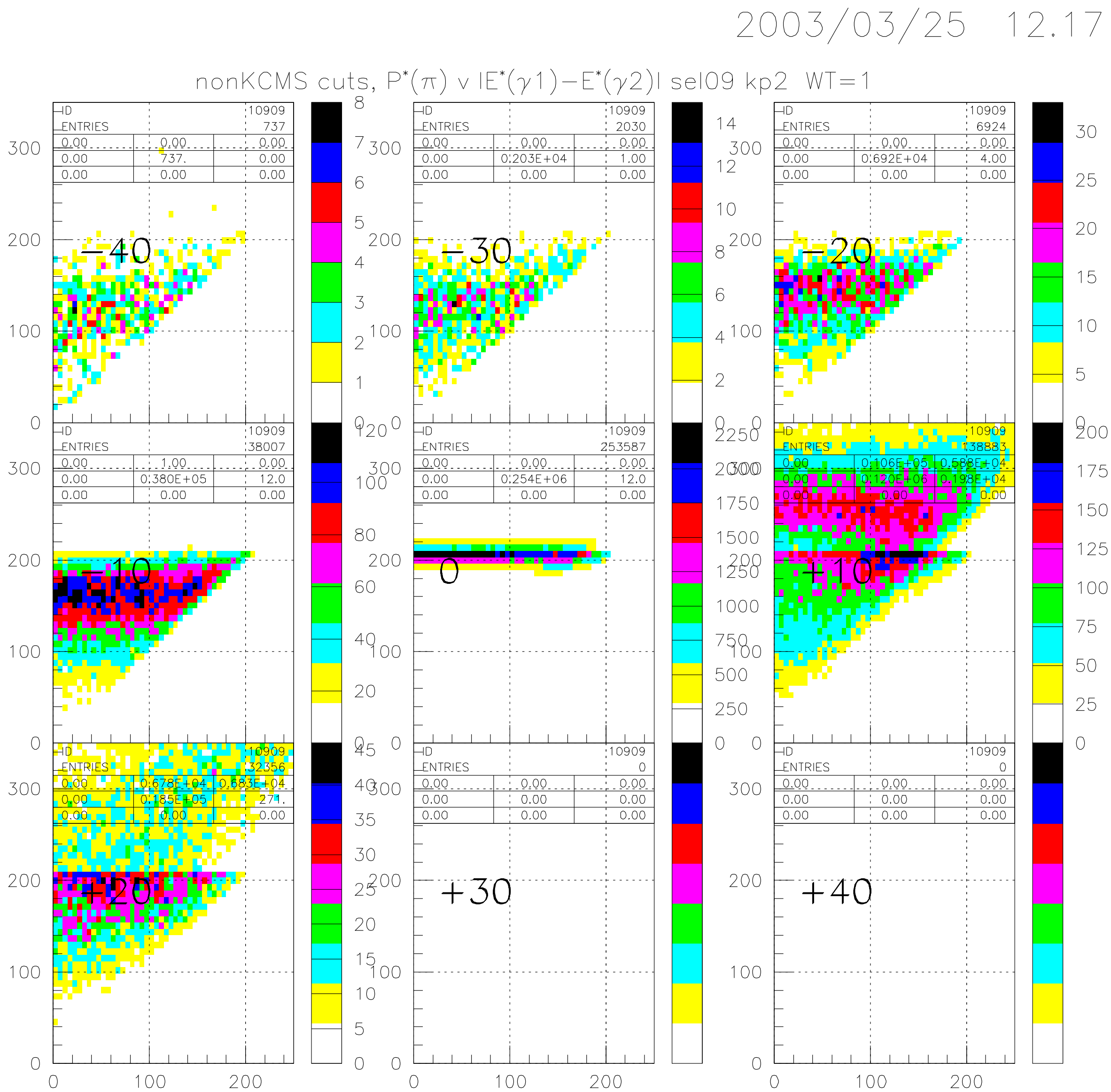


Figure 4: $P^*(\pi^0)$ *vs* $|E^*_{\gamma 1} - E^*_{\gamma 2}|$ distributions for the 9 different times with respect to the bunch.

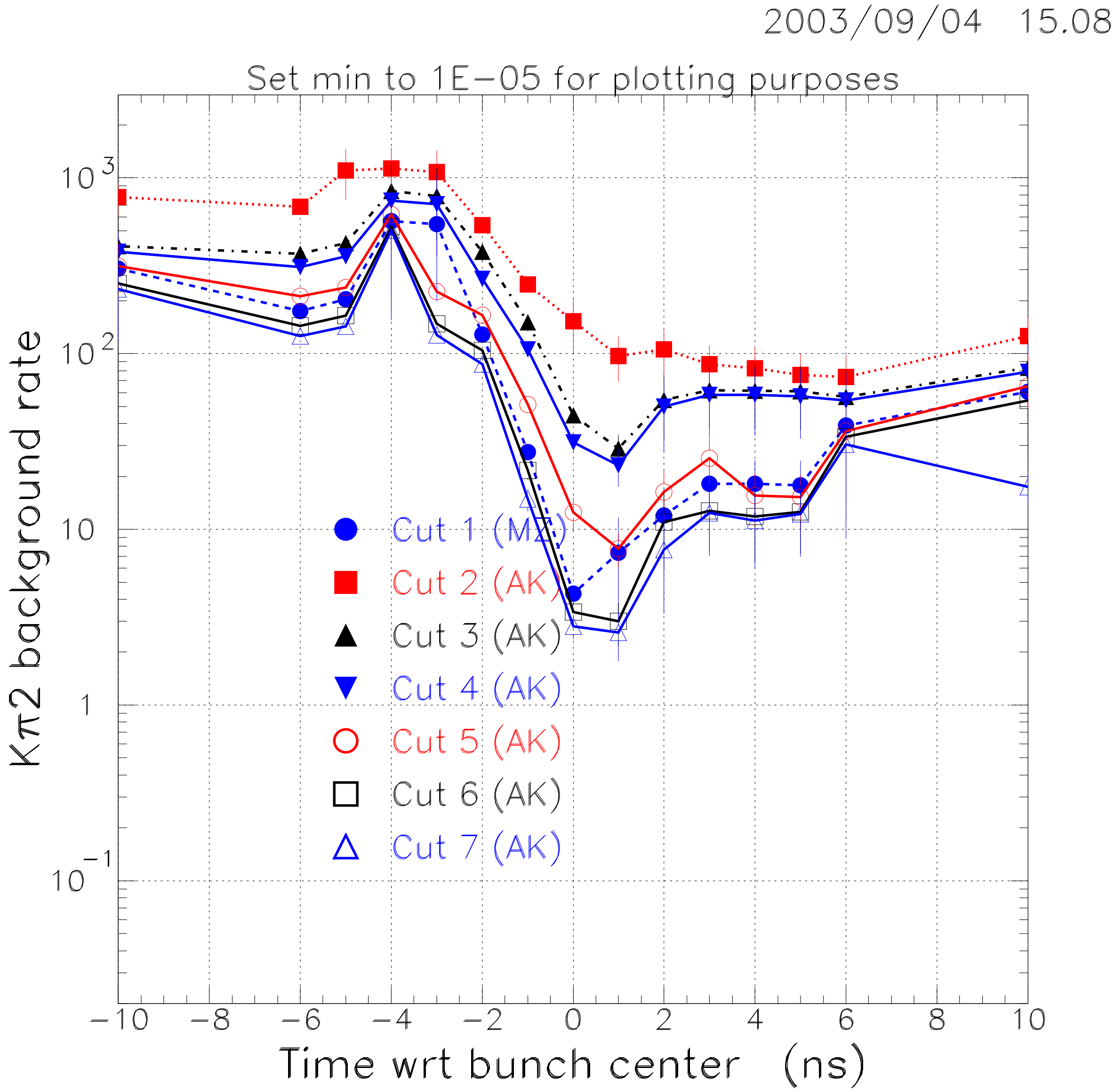


Figure 5: Absolute $K^0_L \to \pi^0\pi^0$ background rates with respect to the bunch center for the -10,+10 ns range.

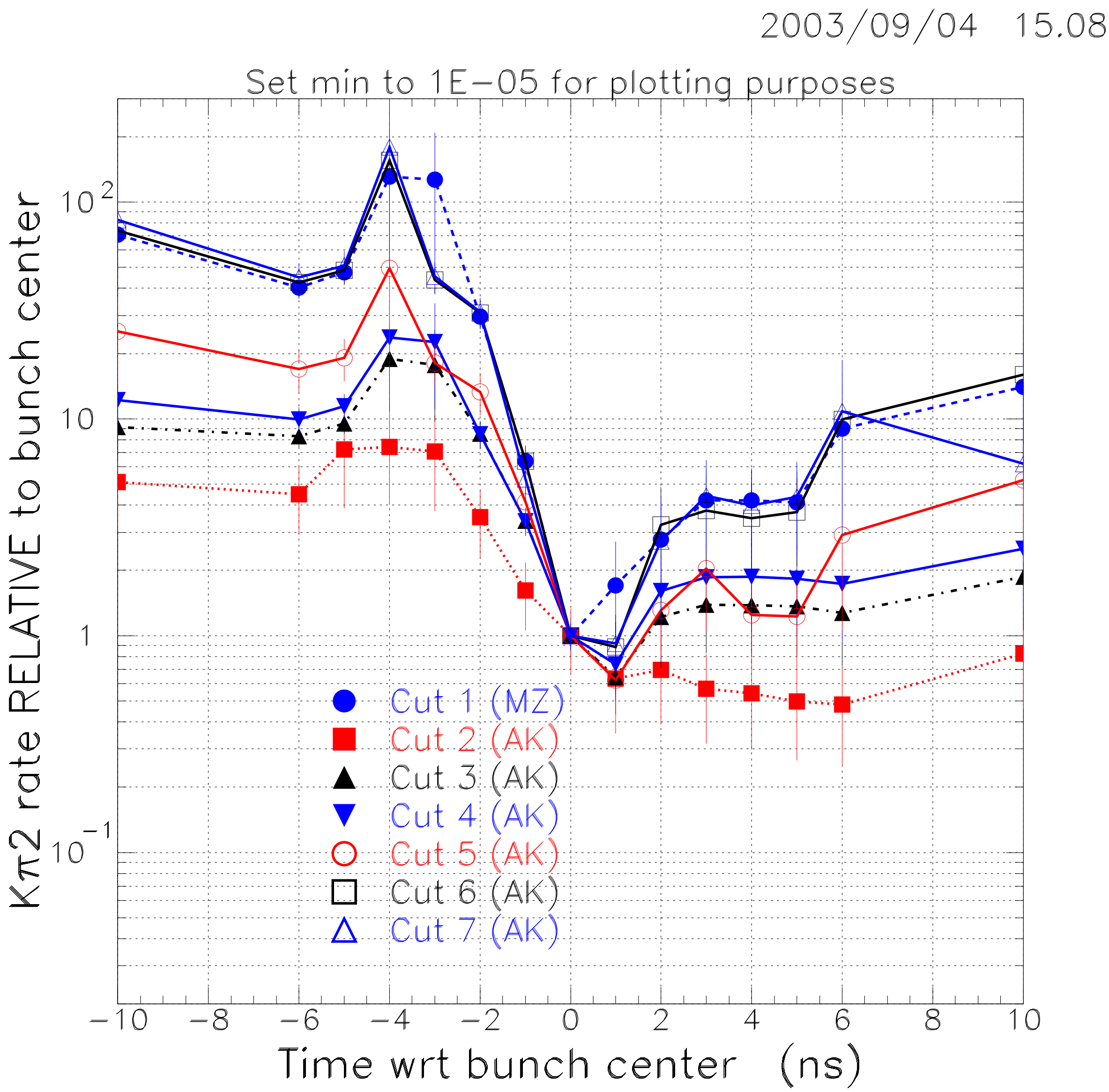


Figure 6: Relative $K_L^0 \to \pi^0\pi^0$ background rates with respect to the bunch center for the -10,+10 ns range.

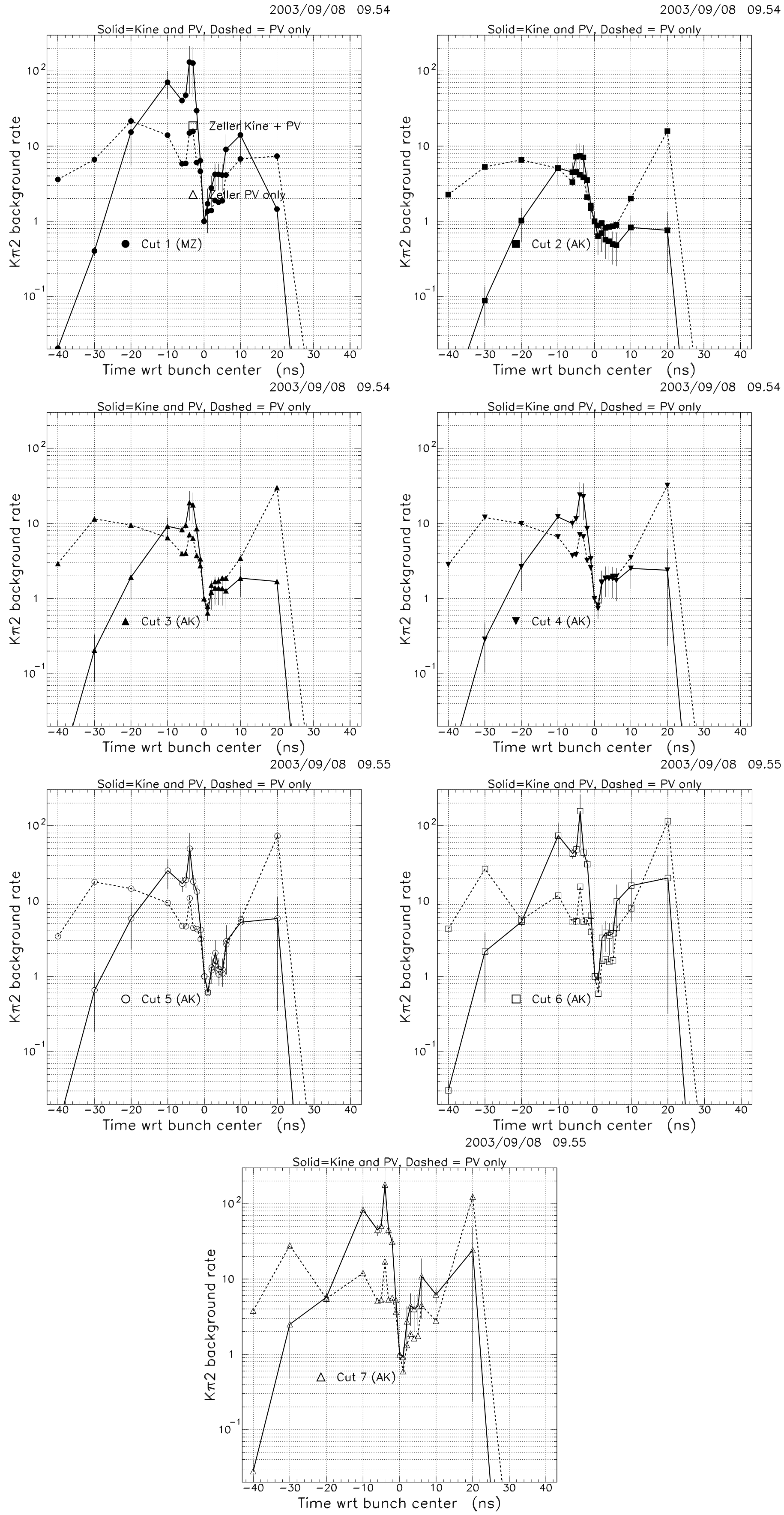




Figure 7: The relative loss of $K^0_L \to \pi^0\pi^0$ rejection for each cut set for kinematics and photon veto combined (solid line) and for photon veto only (dashed line). Statistical uncertainties are omitted for the photon veto only result. The results reported to me by Mike Zeller for his simulation are also shown.

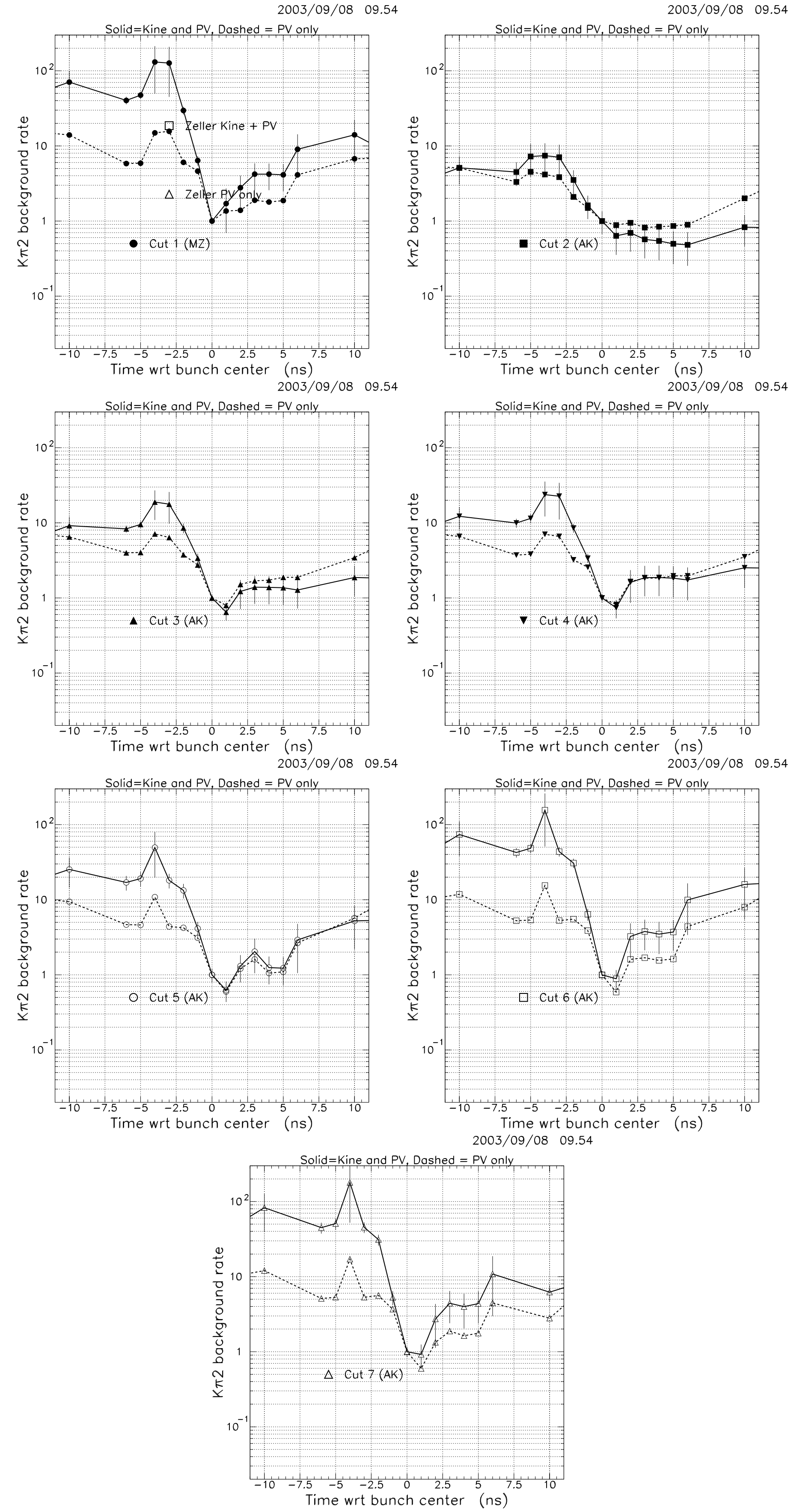




Figure 8: The relative loss of $K_L^0 \to \pi^0\pi^0$ rejection for each cut set for kinematics and photon veto combined (solid line) and for photon veto only (dashed line) for the -10,+10 ns range. Statistical uncertainties are omitted for the photon veto only result. The results reported to me by Mike Zeller for his simulation are also shown.